USAF
PRAM PROGRAM OFFICE

PRAM PROJECT FINAL REPORT

Advanced CMS

C-141 SYSTEM PROGRAM MANAGEMENT DIRECTORATE

18 October 1994

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Approved for public release; distribution is unlimited.

Approved by:

WILLIAM P. HALLIN
Major General, USAF
Commander, Warner Robins ALC

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1. EXECUTIVE SUMMARY

Problem Statement

WR-ALC uses the Capacitance Measurement System (CMS) to determine fastener hole quality on C-141 and F-15 aircraft. The size of the original CMS system (300 pounds) made it inconvenient in the work area and affected reliability, accuracy, and repeatability of the system. Vibration problems, associated with transporting the unit across the flight line, affect the system reliability. Accuracy and repeatability are affected by the need of a long reach cable for the hole probe to reach all work areas on the aircraft without constantly moving the machine from location to location. The fifty foot reach cable that is required for the CMS is shielded; however, electromagnetic interference will still occur.

Corrective Action

A miniaturized version of the CMS was envisioned as a solution that would solve the problems associated with the system. A small, easily portable unit would enable the operators to place the equipment much closer to the work area. This portability eliminates the transportation problems, which reduces reliability concerns. The ability to place the unit in the work area also eliminates the need for a long reach cable, thus reducing electromagnetic interference problems.

Resulting Situation

This program improved the productivity of the CMS by miniaturizing the electronics and incorporating a notebook computer for control. This Advanced Capacitance Measurement System (ACMS) is capable of making the inspections for fastener hole quality, providing the operator with accept/reject decisions and feedback using a monochrome display. The ACMS is small and easily transportable, which reduces transportation induced degradation. This reduced size also allows portability around the work site, greatly reducing the length of the hole probe reach cable and eliminating interference problems.

Implementation Costs and Schedule

A single system was purchased with PRAM funds and was delivered on 4 Aug 94 at a cost of $42,500.00 for the unit and $6,376.00 for a warranty. Four additional systems are currently on contract with delivery to begin in Oct 94 with one system delivered per month. These four systems were purchased for the C-141 Center Wing Box Replacement Program and will cost a total of $163,232.00 for the units and $24,488.00 for warranties. Due to the similarity of the computer operating environment between ACMS and the original CMS, operator training is not required. Implementation will be considered complete with the delivery of the fifth system in November 1994.

PRAM Investments and Returns

The system was developed on a cost sharing basis between the contractor, Measurement Systems Inc. and the government. This situation helped the contractor by resulting in a system that is much easier to market than the original CMS. Returns to the government include: reduction in maintenance costs due to reliability problems associated with the original CMS, reduction in probe replacement costs associated with broken probes (due to a shorter reach cable and less opportunity for accidents), reduction in labor requirements, and an increase in aircraft availability due to quicker inspections of critical areas.

2. INTRODUCTION

CMS utilizes the property of electrical capacitance to vary according to distance as a means of determining fastener hole shape and diameter. Probes for the CMS are fabricated by silk screening small plates around the circumference of a ceramic core. The plate on the probe acts as one-half of the capacitor with the hole wall acting as the other half. An electric current is passed across the gap between the probe plates and the hole wall. The capacitance is measured and sent to a computer for processing. Up to 48 plates are contained on a single probe which gives very detailed information about the hole. The entire process of taking the capacitance readings and processing the information requires about three seconds.

The original CMS is a very large system. A Sears tool cart is used to house the unit and the resultant gross weight is approximately 300 pounds. The size and weight of the unit dictate that once located at the inspection site, the unit is not moved unless absolutely necessary. In order to reach all possible inspection sites on the aircraft wings, a long reach cable is required. Most work accomplished on the C-141 aircraft using CMS requires a 50-foot-long reach cable. This cable is highly susceptible to electromagnetic interference due to the length. Even with shielding interference problems make calibration and use difficult.

CMS was developed by the now, defunct GETEX division of Lockheed. When the GETEX division was eliminated, an independent company named Measurement Systems Inc.(MSI) was formed and given exclusive rights of manufacture for the CMS by Lockheed. MSI has made significant improvements to the hardware and software of the CMS. An unsolicited proposal was submitted by MSI to develop the ACMS. The purpose of the development of the ACMS was envisioned as a solution to the problems associated with the size of the CMS by miniaturizing the components.

The C-141 Product Directorate is the largest single user of CMS, with 40 systems currently in use. The ACMS PRAM project was submitted by the C-141 Structural Engineering Section, WR-ALC/LJLEA. The C-141 Contracting Branch, WR-ALC/LJKA, developed the cost sharing contract with MSI. Development of the ACMS was accomplished by MSI, with WR-ALC/LJLEA developing the governing specification. Testing of the prototype systems was accomplished by the C-141 Maintenance Division, WR-ALC/LJP.

3. TECHNICAL INVESTIGATION

Statement of the Problem

The original CMS is a very large system. A Sears tool cart is used to house the unit and the resultant gross weight is approximately 300 pounds. The size and weight of the unit dictate that once located at the inspection site, the unit is not moved unless absolutely necessary. In order to reach all possible inspection sites on the aircraft wings, a long reach cable is required. Most work accomplished on the C-141 aircraft using CMS requires a 50-foot-long reach cable. This cable is highly susceptible to electromagnetic interference due to the length. Even with shielding interference problems make calibration and use difficult.

Investigation and Findings

The CMS was first used by WR-ALC on the C-141 Center Wing Refurb Project in 1986. There were twelve systems in use for inspecting holes on the upper surface of the center wing. With the start-up of work at the inner to outer wing joints, more systems were acquired and longer cables were required to reach all inspection areas on the aircraft. The longer cables resulted in an increase in problems due to interference. Better shields for the cables were developed by the manufacturer, MSI, but problems still persist. The ACMS was determined to be the best solution to the interference problems by allowing the test system to be moved closer to the inspection area on the aircraft, rather than getting a longer cable.

Technical Approach

Because the expertise in the system was contained primarily at MSI, they were utilized contractually to develop the ACMS. The contract was divided into five basic tasks as follows:

- Phase I: Prototype Redesign and Fabrication
- Phase II: Prototype Test and Evaluation
- Phase III: Final Design and Packaging
- Phase IV: Final Test and Evaluation
- Phase V: Fabrication of Deliverable Systems

Phase I: Prototype Redesign and Fabrication

This phase consisted of hardware design, software development, and fabrication of a prototype. Hardware design consisted of choosing a controller for the system, designing the miniaturized circuit boards to obtain and process capacitance information, and identifying the power supply options. Software development was comprised of writing existing code in a format that was compatible with the controller and deleting or changing outdated code from the original CMS. The prototype was required to demonstrate the feasibility of integrating the chosen components with the software.

Phase II: Prototype Test and Evaluation

The Prototype Test was performed by Air Force personnel at Robins AFB in the C-141 Production Division. The contractor interfaced with the government during testing and evaluation to insure that any needed changes were identified before final design.

Phase III: Final Design and Packaging

During this phase, the contractor incorporated changes identified during the prototype testing and evaluation phase. The final configuration baseline was also defined at this point. After the above decisions were finalized, the contractor fabricated a final design assembly for testing.

Phase IV: Final Test and Evaluation

The final design assembly was tested and evaluated by the contractor at Robins AFB. The accuracy and repeatability of the ACMS was compared with corresponding results from the CMS. The software was thoroughly tested for faults and corrections were incorporated into the final design. The final design was also evaluated for accessing ease of inspector, operation, and interface.

Conclusions and Recommendations

The ACMS, developed under this PRAM project, is a very useful tool for inspection of any hole or bore. Improvements over the CMS have reduced the cost of the system while improving performance.

4. LESSONS LEARNED

LESSONS LEARNED

ADVANCED CAPACITANCE MEASUREMENT SYSTEM

A complete test of a prototype system, by the using personnel, will result in a better system. The testing environment should be the actual environment in which the system will be used, if possible. Training users on a new system can present problems, but in our case this was not a factor since the software on the new system was very similar to that of the old system.

Obtaining input from the users during the design and prototype testing resulted in a system which is much more user friendly. The developed system also proved to have a better efficiency of operation. The users are more likely to utilize a system in which they had some input into the design.

5. IMPLEMENTATION

Approach

There is currently one ACMS in use and four more on order. This complements the 40 CMS systems in use by the C-141 Product Directorate. Due to the costs involved, there are no plans to replace all of the CMS systems with ACMS. If new projects are encountered where additional systems are required, then the ACMS will be purchased. There is a current study under way to determine if probe breakage is reduced with the new system. The probes used by both CMS and ACMS are very expensive and break frequently. One theory is that the probe breakage will be reduced with ACMS due to the shorter length cable. If probe breakage is significantly reduced by ACMS, then the savings resulting from reduced probe breakage will outweigh the cost of the new system. If the study shows that ACMS is beneficial from a probe breakage viewpoint, then the ACMS will be purchased to replace the CMS.

Status

One ACMS is in use with four more on order. If the study mentioned above yields favorable results for the ACMS, then more systems will be purchased. Current plans are to run the study until January 1995 to allow sufficient data to be collected.

Validation of Savings

During the first year of operation, the five ACMS systems will be tracked for any repairs required. Repair information, along with usage estimates, will be used to determine ACMS system reliability. Additionally, probe breakage will be tracked. The purpose for this is to determine if the short reach cable results in a reduction in probe breakage.

6. ECONOMIC SUMMARY

The ACMS was developed under a cost-sharing contract with MSI. Most of the design and development cost was provided by MSI. PRAM funding was used primarily to bring in outside expertise in developing the new system.

Total Project Cost: $264.4K

PRAM Project Cost: $76.6K

a. Design & develop modification	$26.1K
b. Build First System	$42.5K
c. Warranty on First System	$6.3K
d. Travel	$1.7K

Non-PRAM Project Cost: $187.8K

a. Build four systems	$163.3K
b. Warranty on four systems	$24.5K

Life-Cycle Savings: $2,200K

Item	Year	Life
a. Reduced Repair Costs	$2.5K	$25K
b. Reduced Acft Downtime	$180K	$425K
c. Reduced Labor Requirements	$175K	$1,750K

Life-cycle savings were computed for a useful life of 10 years. The reduced repair costs are based on the total spent on all systems for repair. Approximately 40 systems have been in use by WR-ALC for the past six years. A total of $252,146.77 has been spent on system repair, which equates to a cost of $1,050/yr per system. A savings of $500/yr per system is based on the estimated improvement in reliability by a factor of two. The reduced repair cost is based on five systems (the one PRAM funded systems and four systems bought by LJ).

Reduced aircraft downtime is based on experience with the prototype system evaluation. The evaluation was performed during the C-141 Center Wing Box Replacement Program in the area of the FS734 frame for a frame replacement. A reduced flow of approximately one day was observed to occur in this area using the ACMS instead of CMS. Since the frame replacement is in the "critical path", this equates to one aircraft down day saved per occurrence. The FS734 frame replacement occurs on average once each aircraft. The number of aircraft remaining to receive a new center wing box is approximately 85 (36 per year). The value of $5,000 per aircraft down day is arbitrary but believed to be a close estimate for purposes of computing savings.

Labor savings are based on the ability to locate the system at the site of inspection. Two operators are required for the original CMS. One operator is required at the computer and one operator is required at the probe. The ACMS reduces the required operators from two to one by allowing both jobs to be performed by the same person because the probe and processing equipment are located together. The savings were computed using 2,080 hours per year for each operator at a labor rate of $16.82 per hour (WG-08). The total was computed for five systems over a ten-year period.

Net Benefits:

Total Savings	$2,200.0K
Total Costs	$264.4K
Net Benefits	$1,935.6K

7. APPROVAL AND COORDINATION

OFFICE SYMBOL	SIGNATURE	DATE
PROJECT OFFICER		18 Oct 94
LJLEA		20 OCT 94
LJLE	Ralph L. Tyner	20 Oct 94
LJLM	Richard L Jones	24 Oct 94
LJL	Wayne L Davidson	24 Oct 94
LJKA	T. Foskey	28 OCT 94
LJ	Charles L Johnson	1 Nov 94
SES		7 Nov 94
PRAM MANAGER	Thomas	8 Nov 94
TIECT		17 Nov 94
TIEC	Stanley K Vinley	22 NOV 94
TIE		9 Dec 94
TI	Alan J.	3 JAN 95

This coordination page indicates agreement at all management levels with the findings and conclusions of the project and actions to be taken to implement the results.

8. APPENDICES

Appendix A: Supporting Documents

List of Maintenance Contracts

Date	Contract Number		Amount
May 4, 1989	F09650-89-M-4226		$2,014.36
Oct 19, 1989	F09650-89-M-9334		$1,108.61
Oct 19, 1989	F09650-90-M-9336		$14,904.03
Dec 6, 1989	F09650-90-M-2057		$2,874.81
Jan 31, 1990	F09650-90-M-3214		$3,757.66
Aug 28, 1990	F09650-90-M-6498		$2,863.35
Oct 4, 1990	F09650-90-C-0274		$74,544.00
Feb 4, 1991	F09650-91-M-2266		$1,079.54
Mar 8, 1991	F09650-91-M-2750		$712.91
Apr 3, 1991	F09650-91-M-3058		$2,083.35
Aug 25, 1991	F09650-91-M-4802		$2,860.05
Aug 1, 1991	F09650-91-M-3864		$2,451.21
Aug 28, 1991	F09650-91-M-4382		$784.77
Oct 1991	F09650-90-C-0274		$70,021.92
Apr 14, 1992	F09650-92-M-2971		$2,308.26
May 14, 1992	F09650-92-M-3327		$1,393.73
Jun 1, 1992	F09650-92-M-2760		$482.69
Jul 15, 1992	F09650-92-M-4033		$1,778.29
Aug 8, 1992	F09650-92-M-4454		$1,194.39
Aug 23, 1993	F09650-93-C-1211		$41,615.18
Nov 22, 1993	F09650-94-P-1572		$2,805.00
Mar 7, 1994	F09650-94-P-4371		$10,662.64
Mar 4, 1994	F09650-94-M-1441		$1,846.02
Aug 31, 1994	F09650-94-M-3445		NTE $6,000
		TOTAL	$252,146.77

Appendix B: Test Reports

Final Design Evaluation Report

MEASUREMENT SYSTEMS INCORPORATED

System Development Evaluation Report

Advanced Capacitance Measurement System (ACMS)

Final Design Evaluatin Report
1 August 1994

Contract F09603-93-C-1165

CDRL Item No. A002

Prepared by: Chris T Ratcliffe

Approved by: [illegible]

System Development Evaluation Report

Advanced Capacitance Measurement System (ACMS)

Final Design Evaluation Report
August 1, 1994

Contract F09603-93-C-1165

CDRL Item Number A002

1.0 **SCOPE:** The purpose of this task was to incorporate all software and hardware design changes identified during the prototype testing and evaluation phase (Prototype Evaluation Report, dated May 11, 1994 is enclosed as Attachment A). The contractor has determined the final design configuration and a final design assembly has been fabricated. The required software changes requested by the Air Force at Robins Air Force Base have been incorporated into the final software configuration.

2.0 **BACKGROUND:** The ACMS was designed and developed to have the same basic capabilities as, and at least the same basic measurement performance, of the current CMS with significantly improved portability. Measurement Systems Incorporated followed a very strict Development Plan insure that the specifications of the contract were met. In most cases the design criteria exceeded the Statement of Work (SOW) requirements.

3.0 **EVALUATION OBJECTIVES:** The objectives of the final evaluation plan was to incorporate every change in the software and hardware identified in the prototype testing phase into the final design configuration. A photograph identified as Attachment B is enclosed showing the final design configuration of the ACMS. The final software version is identified as ACMS Software Revision 1.00, Part Number ACM0501-101A. A Software Revision Activity Report, ACMS Revision 1.00, dated July 21, 1994, identified as Attachment C is enclosed.

4.0 **EVALUATION CRITERIA:** The evaluation criteria used for the final evaluation was 1) that which was listed in Specification 91-LJLE-013, Revision 1 dated 06-28-93 and which was included as part of Contract F09603-93-C-1165, and 2) additional criteria identified in the Prototype Evaluation Report.

SCHEDULE BASELINE

	Event	Baseline	Estimated	Contract Required	Actual
	TTO Funds Committed	Oct 92			Oct 92
	Contract Award	Jul 93	Jul 93	Sep 93	Sep 93
	Phase I	Jan 94	Jan 94	Mar 94	Jan 94
	Hardware Redesign				
	Software Development				
	Prototype Fabrication				
	Phase II	Feb 94	Feb 94	Apr 94	Mar 94
	Prototype Test				Apr 94
	Evaluate Results				
A001	Prototype Evaluation Report	Mar 94	Mar 94		May 94
	Phase III	May 94	May 94	Jul 94	Jul 94
	Design Changes				
	Final Assembly Fabrication				
	Phase IV	Aug 94	Aug 94	Oct 94	Jul 94
	Acceptance Testing				
	Evaluation Results				
	Update Software				
A002	Final Design Evaluation Report	Sep 94	Sep 94		Aug 94
	Phase V	Oct 94	Oct 94	Dec 94	
	Design Changes				
0002	Deliverable System				
A003	Deliverable Software				
	Final Report	Dec 94	Dec 94		

MATERIAL INSPECTION AND RECEIVING REPORT

FORM APPROVED OMB
No. 0704-0248
EXPIRES DEC. 31, 1990

Public reporting burden for this collection of information is estimated to average 35 minutes per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0248), Washington, DC 20503.

1.PROC. INSTRUMENT IDEN. (CONTRACT): F09603-93-C-1165
(ORDER) NO.:
6.INVOICE: 01398
7.PAGE: 1 OF 1
8.ACCEPTANCE POINT: ORIGIN

2.SHIPMENT NO.: MSI0002A
3.DATE SHIPPED: 1-Aug-94
4.B/L
TCN
5.DISCOUNT TERMS: NET 30 DAYS

9.PRIME CONTRACTOR CODE OACF2
Measurement Systems Incorporated
2262 Northwest Parkway, Suite B
Marietta, Georgia 30067

10.ADMINISTERED BY CODE S1103A
DCMAO Atlanta
805 Walker Street
Marietta, Georgia 30060-2789

11.SHIPPED FROM (If other than 9) CODE FOB: D
(SEE BLOCK 9)

12.PAYMENT WILL BE MADE BY CODE SC1020
DFAS - Columbus
DFAS - CO/Southeast
P.O. Box 182225
Columbus, Ohio 43218-2225

13.SHIPPED TO CODE
WR-ALC/LJLEA
Attn: Mr. Edward Pratt
270 Ocmulgee Ct
Robins AFB, Georgia 31098-1646

14.MARKED FOR CODE
WR-ALC/LJLEA
Attn: Mr. Edward Pratt
270 Ocmulgee Ct
Robins AFB, Georgia 31098-1646
Contract: F09603-93-C-1165
Requisition Nr: FD2060-93-30012-01-02
PR LI: 0002

15 ITEM NO.	16 STOCK/PART NO.	DESCRIPTION (Indicate number of shipping containers - type of container - container number.)	17 QUANTITY SHIP/REC'D*	18 UNIT	19 UNIT PRICE	20 AMOUNT
0001	AB	System Development Evaluation Report Final Design Evaluation Report (O/T-92-35094)	1	LO	$8,250.00	$8,250.00
0001	AC	Computer Software (DI-MCCR-80700)	1	LO	$4,600.00	$4,600.00
0004		Travel Necessary to Perform Requirements of Statement of Work (SOW) ACRN: AA PR NR: FD2060-93-30012-01-02	1	LO	$1,150.00	$1,150.00
0005		Per Diem in Support of CLIN 0004 ACRN: AA PR NR: FD2060-93-30012-01-02	1	LO	$520.00	$520.00
		TOTAL INVOICE AMOUNT				$14,520.00

21. PROCUREMENT QUALITY ASSURANCE

A.ORIGIN
☐ PQA ☐ ACCEPTANCE of listed items has been made by me or under my supervision and they conform to contract, except as noted herein or on supporting documents.

DATE SIGNATURE OF AUTH GOVT REP
TYPED NAME
OFFICE

B.DESTINATION
☐ PQA ☒ ACCEPTANCE of listed items has been made by me or under my supervision and they conform to contract, except as noted herein or on supporting documents.

4Aug94 Edward Pratt
DATE SIGNATURE OF AUTH GOVT REP
TYPED NAME
AND TITLE

22. RECEIVER'S USE
Quantities shown in column 17 were received in apparent good condition except as noted.

4Aug94 Edward Pratt
DATE RECEIVED SIGNATURE OF AUTH GOVT REP
TYPED NAME
AND OFFICE

*If quantity received by the Government is the same as quantity shipped, indicate by ( ) mark, if different, enter actual quantity received below quantity shipped and encircle.

23.CONTRACTOR USE ONLY

DD Form 250, JAN 90 *Previous editions are obsolete.* 311/051
*U.S.GPO:1990-0-261-056/0

08/01/94

CMS II CUSTOM SYSTEM FOR WR-ALC
WITHOUT HCU AND MANUAL
HCU CABLE ONLY, NO OTHER CABLES
AC POWERED, VER 1.00 SOFTWARE

- ACM0003-101A CAPACITANCE MEASUREMENT SYSTEM II
  - ACM0401 FRONT COVER
    - ACM0402 NAME PLATE
    - AMC0403 COVER BODY
  - ACM0221 CABLE ASSY HAND CONTROL
  - ACM0100 MEASUREMENT UNIT
    - ACM0157 DRIVE BAY MU CHASSIS
    - ACM0152 FRONT MU CHASSIS
    - ACM0153 TRANSITION MU CHASSIS
    - ACM0154 BODY MU CHASSIS
    - ACM0155 TOP MU CHASSIS
    - ACM0156 REAR COVER MU CHASSIS
    - ACM0158 HARD DRIVE PLATE
    - ACM0159 REAR BUMPER MU CHASSIS
    - ACM0160 FT. BUMPER MU CHASSIS
    - ACM0101 EU ASSY
      - ACM0111 D/A BOARD ASSY ASSY
        - ACM0113 CUSTOM LOGIC
        - ACM0112 D/A BOARD SCHEMATIC
        - AMC0110 D/A BOARD PWB
      - ACM0121 PROCESSOR BD ASSY
        - ACM0120 PROCESSOR PCB
        - ACM0126 CUSTOM LOGIC
        - ACM0124 CUSTOM LOGIC
        - ACM0125 CUSTOM LOGIC
        - ACM0123 FIRM WARE
        - ACM0127 CUSTOM LOGIC
        - ACM0122 PROCESSOR BD SCHEMATIC
      - ACM0133 TOP SHIELD
      - ACM0132 MOUNTING PLATE
      - ACM0142 CABLE ASSY BOARD/PROBE
      - ACM0143 CABLE ASSY INTERCONNECT
      - ACM0134 SHIELD BOARD
      - ACM0135 SIDE SHIELD
    - AMC0170 WIRING DIAGRAM
    - ACM0171 CABLE ASSY HDD (IDE)
    - ACM0172 CABLE ASSY FLOPPY DISK
    - ACM0173 CABLE ASSY KEYBOARD
    - ACM0174 CABLE ASSY PRINTER
    - ACM0175 CABLE ASSY HCU/EU
    - ACM0180 CABLE ASSY GND/MU
    - ACM0176 CABLE ASSY SERIAL/EU
    - ACM0177 CABLE ASSY DISK POWER
    - ACM0178 CABLE ASSY COMPUTER PWR
    - ACM0179 CABLE ASSY A.C. INPUT
    - ACM0191 FLOPPY DISK DRIVE
    - ACM0192 HARD DISK DRIVE
    - ACM0193 POWER SUPPLY
    - ACM0190 COMPUTER CONTROLLER
  - ACM0501-101A SYSTEM SOFTWARE

ATTACHMENT A

August 1, 1994

PROTOTYPE EVALUATION REPORT

MEASUREMENT SYSTEMS INCORPORATED

System Development Evaluation Report

Advanced Capacitance Measurement System (ACMS)

Prototype Evaluation Report
May 11, 1994

Contract F09603-93-C-1165

CDRL Item No. A001

Prepared by: ______________________________

Approved by: ______________________________

System Development Evaluation Report

Advanced Capacitance Measurement System (ACMS)

Prototype Evaluation Report
May 11, 1994

Contract F09603-93-C-1165

CDRL Item No. A001

1.0 **SCOPE:** The purpose of this task was to evaluate a working prototype Advanced Capacitance Measurement System (ACMS) by the Air Force at Robins Air Force Base. During the month of March 1994, the completed prototype system designed and fabricated during Phase I of the contract was provided by Measurement Systems Incorporated (MSI) to engineering and maintenance personnel at Robins AFB.

2.0 **BACKGROUND:** The ACMS was designed and developed to have the same basic capabilities as, and at least the same basic measurement performance, of the current CMS with significantly improved portability. Measurement Systems Incorporated followed a very strict Development Plan (enclosed as Attachment A) to insure that the specifications of the contract were met. In most cases, the design criteria exceeded the Statement of Work (SOW) requirements.

3.0 **EVALUATION OBJECTIVES:** The objective of the evaluation plan was to present a working prototype system to determine potential problems with the hardware configuration and operational software. A planning meeting held at Robins AFB on January 14, 1994 (Summary sheet attached as Attachment B) selected the desired system configuration as well as a software package which could be properly evaluated during the Prototype Test and Evaluation Phase II. It was determined during this meeting that the government preferred the AC powered ACMS over the battery powered, LCD system which was specified in the original specification.

4.0 **EVALUATION CRITERIA:** The evaluation criteria used for the prototype evaluation was 1) that which was listed in Specification 91-LJLE-013, Revision 1 dated 06/28/93 and which was included as part of Contract F09603-93-C-1165, and 2) additional criteria agreed to at the January 14, 1994 meeting. These criteria and the accompanying evaluation results are summarized in the following table.

Specification 91-LJLE-013 Revision 1, 06/28/93 System Requirements	Phase II Contract F09603-93-C-1165 Prototype Evaluation Results
3.1 The system shall be contained in a small, portable package.	Achieved. System weighs 20 lbs.
3.2 The system shall be totally self-contained with the exception of external power supply.	Achieved.
3.3 Power supply shall be provided in the form of rechargeable batteries and 110V AC. A means of recharging the batteries shall be provided with the system.	Battery power requirement deleted per meeting 1/14/94. System is powered by 110V AC.
3.4 The system shall use electrical capacitance to determine fastener hole dimensions.	Achieved.
3.5 A computer (controller) shall be utilized to control the system. The controller shall be MS-DOS based, with a minimum of two MB of RAM and a minimum of ten MB of permanent storage. The controller shall also contain a 3.5 inch micro-floppy disc drive along with a full alpha-numeric keypad and a CRT display. Through the screen input such as "Touch-Screen" or "Light-Pen" may be used in lieu of a key pad for alpha-numeric input.	Achieved. The MS-DOS computer (controller) has two (2) MB of RAM and 130 MB of permanent storage. The controller has a "Touch-Screen" for alpha numeric input and a 3.5 inch micro-floppy disc drive.
3.5.1 The computer shall provide textual feedback to the operator with the following information:	
3.5.1.1 Assembly number.	Achieved.
3.5.1.2 Hole number.	Achieved.
3.5.1.3 Reading number.	Achieved.
3.5.1.4 Drawing number.	Achieved.
3.5.1.5 Minimum hole diameter.	Achieved.
3.5.1.6 Average hole diameter.	Achieved.
3.5.1.7 Maximum hole diameter.	Achieved.
3.5.1.8 Minimum diameter limit.	Achieved.

3.5.1.9 Maximum diameter limit.	Achieved.
3.5.1.10 Accept/Reject.	Achieved.
3.5.1.11 A picture of the hole shall be provided by the computer in the form of a plot on the display screen. A hole plot shall be available in the following forms:	Achieved.
3.5.1.11.1 A circle plot which shows the relative radius measurement of each probe segment in relation to the maximum and minimum limits.	Achieved.
3.5.1.11.2 A mathematically scaled linear plot which plots the diameter at each probe layer against the probe segment.	Achieved.
3.5.1.11.3 A linear pot approximating a vertical cross section of the hole through each segment.	Achieved.
3.5.2 The 3.5 inch micro-floppy disc drive shall be utilized for storing all of the information obtained.	Achieved.
3.5.3 The computer shall be capable of user setup.	Achieved.
3.6 The system shall be capable of calibration to within +/-0.00004 inches in the operating environment and repeatable accuracy to within +/- 0.0002 inches.	Achieved.
3.7 Calibration of the system shall utilize existing calibration equipment.	Achieved.
3.8 The ACMS shall utilize the same probes which are used by CMS.	Achieved.
3.9 Software for the system shall be written in C language. Software shall be provided with the system to perform the following functions:	Achieved.
3.9.1 Security in the form of operator identification and password input.	Achieved.
3.9.2 Set up of user defined parameters.	Achieved.
3.9.3 User input of fastener hole limits.	Achieved.
3.9.4 User input of drawing information required to test fastener holes in an assembly.	Achieved.

3.9.5 Review and plots of previously stored data.	Achieved.
3.9.6 Operator calibration of probes to the system.	Achieved.
3.9.7 Full operation of the system for hole inspection, and calculation of results.	Achieved.
3.10 Software shall be provided in HP-Basic which is compatible with the Hewlett-Packard model A1305A computer to perform the following functions:	Requirement for HP-basic compatibility deleted per meeting 1/14/94.
3.10.1 Review and plot data which was stored on the 3.5 inch flexible discs.	Achieved.
3.10.2 Translate existing drawing information from the HP-Basic format to the new format for transfer to the ACMS computer.	Requirement for HP-basic compatibility deleted per meeting 1/14/94.
3.11 Accept/Reject decisions shall be provided to the operator upon inspection of a hole.	Achieved.
3.12 Physical Dimensions: The ACMS, in the final packaged version, shall be capable of entry into a C-141 fuel tank, therefore the largest component shall pass through the opening in a number four upper center wing panel access hole (ref. Lockheed drawing 3W11304). Reference: Basic opening is an oval, 11.88 inches X 17.88 inches with a 5.94 inch radius at all corners.	Achieved. The final ACMS package is housed in a 10.75 x 12 x 13 inch enclosure and easily fits in the C-141 fuel tank #4 upper center wing panel access hole.

January 14, 1994 Meeting Additional Requirements	Phase II Prototype Evaluation Results
a. Ease of use: Includes handling of unit, ease of screen viewing, etc.	Achieved.
b. Reliability and Maintainability: Total operating time, number of failures, and type of failure to be recorded.	Achieved. No failures reported during eight (8) weeks of evaluation..
c. Software: The software will be evaluated for glitches and user friendliness. The software will also be evaluated to insure all aspects are available which are required by the contract.	Achieved. Please see attached Deficiency Report Forms, Attachment C.
d. Evaluation period will be three (3) weeks	Prototype system was at Robins AFB for eight (8) working weeks.

5.0 **EVALUATION SUMMARY:** The ACMS has been successfully evaluated on the C141B Center Wing Box Replacement Program. The operators found the system very easy to use and greatly improved productivity. Measurement Systems Incorporated provided all operator training and software assistance during this trial and evaluation period. The contractor interfaced with the government on a weekly basis in order to insure that all needed changes were identified. These changes are identified on the attached Deficiency Report Forms (enclosed as Attachment C). All changes will be made prior to commencing Phase III of this contract.

SCHEDULE BASELINE

	Event	Baseline	Estimated	Contract Required	Actual
	TTO Funds Committed	Oct 92			Oct 92
	Contract Award	Jul 93	Jul 93	Sep 93	Sep 93
	Phase I Hardware Redesign Software Development Prototype Fabrication	Jan 94	Jan 94	Mar 94	Jan 94
	Phase II Prototype Test	Feb 94	Feb 94	Apr 94	Mar 94 Apr 94
	Evaluate Results				
A001	Prototype Evaluation Report	Mar 94	Mar 94		May 94
	Phase III Design Changes Final Assembly Fabrication	May 94	May 94	Jul 94	
	Phase IV Acceptance Testing Evaluation Results Update Software	Aug 94	Aug 94	Oct 94	
A002	Final Design Evaluation Report	Sep 94	Sep 94		
	Phase V Design Changes	Oct 94	Oct 94	Dec 94	
0002	Deliverable System				
A003	Deliverable Software				
	Final Report	Dec 94	Dec 94		

ATTACHMENT A

May 17, 1994

ACMS DEVELOPMENT PLAN

ACMS Development Plan
November 2, 1993

Tasks are subdivided into four basic areas. 1) Refine Basic Performance, 2) Component and Subsystem Development, 3) Software Development, and 4) Integration/Verification/Documentation. We would foresee three newly defined milestones in the completion of the project. 1) Construction of 3 "breadboard" prototypes, 2) Construction of 6 "engineering" (1 DC for RAFB eval., 4 DC to deliver to RAFB, and 1 AC for MSI) prototypes concurrent with the begining of RAFB acceptance testing, and 3) Project Completion.

We define a "breadboard" prototype as an ACMS with the current board set, using the old HCU, running the contemporaneous development version of EU and system software. Of the first three "breadboard" prototypes, 2 will be AC versions and 1 will be battery powered with the Computer Dynamics LCD computer in-house. The three painted encosures will be used. These 3 units will serve for development and demonstration for the next 12 weeks. The goal of these breadboard prototypes is to have the accuracy and repeatability of the final production units.

We define an "engineering" prototype as an ACMS with enclosure modifications in place, the 2nd layout of the new digital board, using the new and the old HCU, with completely functional EU and system software. The phasing of the RAFB contract indicates that the system must have all software features included for the first evaluation. This "engineering" prototype will be able to enter the RAFB evaluation phase.

Completion obviously indicates the ability to proceed with production. Internal engineering and external user documentation must be complete. A service/support plan must be complete.

ACMS Task List

Refine Basic Performance

1. Develop Effective Enclosure Shielding

We are still experiencing some problems bringing the new EU boards on line, but for the most part they work very well. When the ACMS prototype was fitted with the LCD display we saw dismal behavior. This has shown to be a problem with shielding in the enclosure. The LCD has a power supply component that is used to fire the flourescent backlight that the EL unit does not have. Separation on the bench of the EU boards from the LCD computer makes the problem go away.

We are developing the specifications for a sheet metal "enclosure" for the two-board package that will provide the desired shielding and ease of assembly of the EU package into the ACMS enclosure. We will need to get mechanical drawings of this part when we are complete and have three built to test with the breadboard prototypes.

2. Construct 3 breadboard prototypes

We currently have 2 analog boards and 1 digital board. We are in the process of building up a total of 3 board sets. Power supply and enclosure components are either in-house or near term delivery. Assembly of 2 additional enclosures should complete the process of determining slight enclosure modifications. We need to test the devil out of these three systems before committing to our next board layout. At this time it appears that the analog board can go to production as is. The digital board will take one more revision.

System software development will not be hampered by this first prototype phase. The only software component that can not be developed on the breadboard prototype is control of the new HCU. However the code to support the old HCU will be developed and this module will be easily adapted when the new HCU is available with the engineering prototype.

We will also be trying out a new PAL (programmable array logic) part during this task. The current PAL's are TTL parts that run rather hot. There are CMOS pin-compatible PAL's that have been identified as potential power saving replacements. We will verify their suitability during this phase.

Component and Subsystem Development

1. New Layout of Digital Board

There are various "scabs" on the first digital board as the result of a few subtle layout errors and some redesign for acceptable performance. These changes will obviously be addressed in the new layout. The interface to the HCU is layed out for the old unit. Our design for the new unit will change the number of signal lines needed to communicate with the HCU. The new digital board will be capable of communicating with either HCU and will be able to recognize which HCU (new or old/none) is on line. There should be little risk in this second layout as the "scab" changes are quite simple and the new HCU interface is not complicated either.

Layout of the board can not take place until the HCU electrical design is complete. Ken Heard has submitted a first pass design which looks suitable. The HCU development task is treated in detail below.

Layout using the OrCAD tools will take Ken about 2 weeks. Board production is 3-4 weeks. Ken indicates that he is still looking for a full-time job and is eager for any assignment we give him for the rest of this year.

2. New Hand Control Unit

The new HCU will use much lower power lamps, and will be capable of communicating more information to the operator via a small LCD display. A 16 character by 2 line display has been preliminarily selected. One line would be used for hole number display. The other line would be used to communicate system status to the operator (i.e. "TAKE AIR READING", "USE 179A PROBE", "OUT OF PAPER", etc.).

We have asked Ken to take a look at his current redesign to see what the ramifications of trying to support the old and the new HCU are. He is to report in with his findings on 11/4. We can then send him off to complete the HCU electrical design and perform layout for the new digital board. This total task is about 3 weeks and should be completed by the first of December.

We should start with the slightly larger Tracewell enclosure for the new HCU to build the first models. We can then decide whether we want to design our own enclosure for the new HCU.

3. Enclosure Design Tweaks

There are several small changes we need to make to the enclosure based on observations of assembly of the Aerofast prototype. Building the two other breadboard prototypes should reinforce and complete the modification list. We need to plan on a 6 week bid/construction cycle for a set of 6 enclosures.

4. Front Cover

The design for the front cover piece is complete and going out for quotation. The design incorporates a change in the bezel width which will be made during enclosure tweaking. For this reason, we can not make front covers for the breadboard prototypes. The lead time on first units is going to be about 4 weeks.

5. Battery System

Sam has been in touch with our battery supplier in regard to packaging and connection of the battery itself. This is still part of his Phase I work but he is somewhat hamstrung by our progress and the responsiveness of the battery vendor. The battery vendor (EAC) is committed to having a proposal for wrapping a 12-pack of batteries with a pressure contact electrical connection by Nov. 15. EAC is also investigating how they can support us in design/production of a remote charger.

We still have to design and test a recharging circuit that will trickle charge the batteries and operate ACMS with the DC unit plugged into the wall. We also need to select an AC power pack (like what the Desk Jet printers work with) that will help us keep a lot of the size and weight of the recharging circuit outside of the ACMS enclosure.

6. Low Power Controller

We have obtained CDI and Emerald's best shots at a low power controller configuration. The Emerald unit uses approximately 20% less power. It also has the programming advantage of going into a "sleep" mode directly from a BIOS screen saver. This would require no timekeeping/control chores in our software. We would simply set the timeout parameter in the screen saver. The BIOS would monitor when that amount of time had passed without activity and shut down accordingly. The BIOS would then monitor the touch screen to wake up. The CDI proposal would give us the ability to go to a standdown mode, but all of the timing/control and monitoring of the screen for wakeup would have to reside in our software. I also think they were a little less thorough in their power budget analysis. The advantage of the CDI approach is that we would not have a custom BIOS that would require modifications to be made if we changed computer products.

Emerald is quoting a 6-8 week lead time on their proposal. They indicate that this design requires a board layout change to accomodate a different power management chip set they propose to use. The quoted NRE for the new board and the BIOS customization is $6000 plus an initial order of 25 units. It is certain that there is some flexibility on this pricing.

We need to go ahead and build one of the breadboard prototypes with the CDI computer and battery power. We also need to gather a little more intelligence on what CDI and Emerald really are offering .

Software Development

1. System Software

Chris and Tim have been promising to define the feature set for many moons and must get together to do this. Three to four properly spaced, two-hour wrestling matches should get the job done. There are 4 weeks between now and Christmas that Tim is in town for ACMS work. We will prioritize the development effort to strike a good balance between marketing needs and linear development progress. We are still 12-16 weeks of actual working software development time away from final featured, debugged code.

2. EU Firmware

Ernie's firmware is at a stage of completion that allows ongoing system test and software development. There are several additional features that he needs to add, and his handling of the old HCU is still a little rough. Although the current firmware allows continued development and testing, there is about 2 weeks of work to the Aerofast firmware to bring it to the point required for completion of breadboard prototypes.

Beyond the breadboard prototype, the firmware must be expanded to support the new HCU and provide some functional system (RAM, ROM) tests. There is a total of 4 weeks of Ernie's efforts here and for firmware debugging.

At the end of the breadboard phase, we would like to try to internalize Ernie's development efforts. We do not have his development tools installed here, and we certainly don't know how to use them. As Ernie moves and gets even a little more retired, we need to minimize our dependence on him. We would suggest that we have Ashley and Ernie come in for a night or two and bring the development system up on Tim's computer. Ernie should definitely finsh the project, but at the conclusion Tim or Ashley should be able to make firmware modifications.

Integration/Verification/Documentation

1. Engineering Documentation

Final drawings for all enclosure related parts.

Internal software documentation for firmware and system software

Assembly drawings and instructions

2. User Documentation

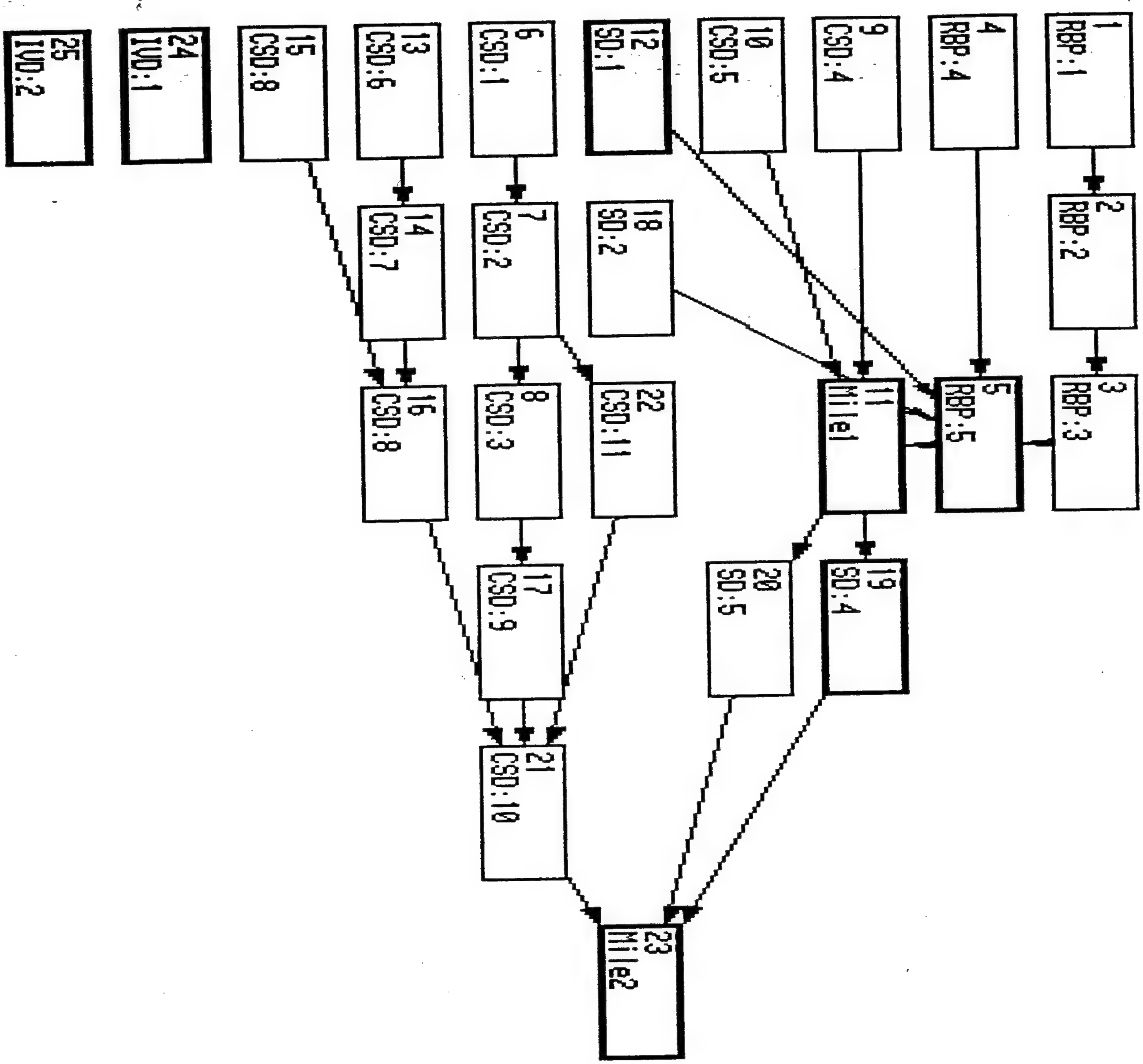
Development of the user documentation can begin in mid-December. At that time the operating software features and screen presentations will be adequately defined that technical writing for the documentation can begin. There are also sections we wish to develop that are more application oriented, care of probe oriented, and troubleshooting oriented. These sections can begin to be worked on as well.

Schedule Overview

December 15	3 complete "breadboard" prototypes (2 AC , 1DC) current board set old HCU CMS quality measurements marketing software
January 28	Production enclosures in house
March 7	Engineering prototypes completely functional new HCU ready for RAFB evaluation user documentation

NETWORK DIAGRAM REPORT
PROJECT: cmsII

CURRENT DATE: 11/03/93
AS OF DATE: 08/16/93



ACMS Electronics Unit
External Reference Specification
Rev. 1.01 Jan. 15

Outline

1.0 Analog Characteristics and Performance

1.1 Data Acquisition Channels

1.1.1 Basic Capability

The ACMS EU will support 48 measurement channels in the standard configuration. These 48 channels will be contained on one DA (Data Acquisition) board.

1.1.2 Extended Capability

It should be considered that future, special purpose derivatives of the EU will support up to 96 shannels by the addition of another DA board with appropriate interconnection and firmware change.

1.1.3 Scaled Capability

It is also highly desirable that the EU support fewer measurement channels (in blocks of 8) by simply not populating the DA board. The EU should be capable of recognizing the maximum number of channels installed at power-up and reset and save this configuration property in RAM.

1.2 Capacitance Ranges Measured

It is desired to measure with opposing capacitor plates as small as .045" x .045" separated by .005". This yields an effective minimum capacitance of .09 pF. It is desired to measure with opposing capacitor plates as large as 1" by 1" separated by .001". This yields an effective maximum capacitance of 224.4 pF.

[DEVELOP SYSTEM CONSTANTS FOR NEW THRESHOLDS AND APPLY TO 5, 10 , 20 MHZ CLOCKS TO SEE IF LARGE CAPACITANCE NEEDS TO BE ADJUSTED DOWNWARD]

[ALSO, DO WE DESIRE TO BE ABLE TO CHANGE THE COUNTER CLOCK BETWEEN CHANNELS IN THE DATA ACQUISTION PROCESS IN CASE THERE ARE PLATES THAT FALL ON EITHER SIDE OF AN INTEGER OVERFLOW FOR A SINGLE CLOCK COUNTER?]

1.2.1 Charge and Discharge Cycle Pulse Widths

The width of the charge pulse and the discharge pulse will be variable in the EU to allow optimization of data acquisition for different ranges of capacitance. These widths should be settable with a 50 usec. resolution. Although the pulse widths can be changed, they will be constant during any given data acquisition cycle.

1.2.2 Clock Frequency of Counter Circuitry

The EU will support counter clock frequencies of 5, 10, 20, and 40 MHz. The clock frequenices will be choosen in the external controller to optimize counter performance to the capacitor plates to be measured. The clock frequency will be variable within a given data acquisition cycle. However, it is only necessary to allow for a different clock frequency for each group of 8 data acquisition channels. This allows the system to match counter performance for each differently sized level of plates in a probe.

1.3 System Repeatability and Resolution

1.3.1 At an ambient temperature of 23 +/- 5 °C, the repeatability of the counting function shall be less than X counts (as determined from the absolute deviation of 10 readings)

1.3.2 In the most sensitive counter range, the system will exhibit a physical measurement resolution of .01 pF as determined by the system repeatability and system constant (counts/pF).

2.0 Embedded Software Capabilities

2.1 Instrument Identification

The instrument shall be capable of responding to a query for serial number identification. This serial number is to be set at the factory by internal DIP switches matching the number on the chassis of the instrument. An 8 bit DIP swith will allow for the first 256 units sold. At such a time that serial number 257 is needed, a hardware/firmware modification will be made.

2.2 Self Test

2.2.1 CPU Test

2.2.2 RAM Test

2.2.3 ROM Test

2.2.4 Timer Test

2.3 Data Acquisition Capabilities

2.3.1 Basic Data Acquisition Process

Upon a trigger command from the external computer, the EU shall make a complete data acquisition cycle. The default data acquisition cycle will be for 48 channels, each measured one time. The results of the data acquisition process are then immediately transfered to the external computer. The content of the data transferred will be detailed in Section 3.0 but consists of 48 single precision floating values.

2.3.2 Alternate Data Acquisition Process.

It is highly desirable to be able to scan just a portion of the available measurement channels. The maximum number of channels (which becomes the operating) default is determined by the firmware through communication with the DA board during power-on or reset. The external computer will be able to send a lower and upper channel to be used in the data acquisition cycle. The lower channel must be greater or equal to 1 (or 0 for 0 based numbering). The upper channel must be less than or equal to the number of hardware channels installed.

The data transfer back to the external computer will only include 1 single precision floating number/channel measured.

2.4 Capacitance Reading Processing Capabilities

2.4.1 Averaging

The EU will be capable of averaging the results of up to 100 data acquisition cycles with a single trigger from the external computer. To save RAM in the EU it is desired to implement averaging on a sample, weighted basis. This algorithm is described in the Appendix. The default EU operation will be 3 averages. A command from the external computer will put the EU in the appropriate averaging mode for the next trigger command. Averaging can be from 2 to 100 readings inclusive.

The average value is then returned to the external computer upon completion of the data acquisition cycle.

2.4.2 Statistical Processing

A process for removing statistical outliers will be available in the EU. This processing mode and averaging are mutually exclusive. A program code to enable one mode will disable the other.

When placed in this mode, the next trigger command will initiate 10 data acquisition scans. This will require storage of the 10 integer counts at each of the (up to) 48 channels. After the 10 scans have been taken, the average and standard deviation of each channel are calculated. For each channel, the 10 readings are compared against the statistical μ +/− σ. All readings on each channel that are <u>not</u> outliers are then averaged. The processed, "averaged" counts are then returned to the external computer.

2.5 HCU Control

3.0 Interface to External Computer

3.1 Hardware Interface Specification

The EU will communicate with the external computer via a standard RS-232 communication port. The communications protocol will be 9600 Baud, 8 data bits, 1 stop bit, no parity.

3.2 Programming Codes

Programming or setup codes will be transmitted to the instrument as ASCII characters. Individual programming codes will be separated by a semicolon (ASCII 59) and the end of programming code transfer will be demarked by the transmission of a carraige return (ASCII 13). For mnemonics that require a number to be sent, there will be no ASCII space character transmitted between the command

ACQ — Acquire data. The data acquisition cycle is determined by other settings for start channel, stop channel, averaging, etc. This mnemonic requires no additional parameters.

STARn	Set the start channel for the next data acquisition cycle. Values for n are 0 to the maximum number of channels (47). If a start channel is sent from the external computer that is larger than the stop channel, the stop channel is made equal to the start channel.
STOPn	Set the stop channel for the next data acquisition cycle. Values for n are 0 to the maximum number of channels (47). If a stop channel is sent from the external computer that is smaller than the start channel, the start channel is made equal to the stop channel.
AVGn	Set the averaging to be used during a data acqusition cycle. Valid ranges for n are 0-100 inclusive. Values of 0 or 1 mean no averaging.
STAT	Enable the statistical processing mode. This mnemonic requires no additional parameters.
SETCn(,n..)	Set the counter clock to the desired frequency. To specify a constant clock frequency for all levels, only one value is sent. To specify values for all six levels, the command will have the form of SETC20,20,20,20,10,5; Values for n are 5, 10, and 20. Out of range values should not be encountered but should be considered. If more than 1 but less than six clock settings are received, the EU will set the clock for all levels to the first number received.
PUMPn	Set the width of the charge cycle (pump) pulse. An integer multiple of 50 usec. will be used (ex. PUMP100; or PUMP350;).
GATEn	Set the width of the discharge cycle (gate) pulse. An integer multiple of 50 usec. will be used (ex. PUMP100; or PUMP350;).
ID?	Return the serial number of the EU
CHANn	Place the EU in a continuous data acquisition mode on the specified channel n (0 to 47). This is a service function only and does not cause data to be returned to the external computer.
CHANOFF	Takes the EU out of the continuous single channel data acquisition mode.
SCANALL	Place the EU in a continuous data acquisition mode scanning all channels. This is a service function only and does not cause data to be returned to the external computer.
SCANOFF	Takes the EU out of the continuous all channel data acquisition mode.
CPU	Initiate the CPU self test. Status of 1 (Pass) or 0 (Fail) is returned
RAM	Initiate the RAM self test. Status of 1 (Pass) or 0 (Fail) is returned
ROM	Initiate the ROM self test. Status of 1 (Pass) or 0 (Fail) is returned
PROM	Initiate the PROM self test. Status of 1 (Pass) or 0 (Fail) is returned
EPROM	Initiate the EPROM self test. Status of 1 (Pass) or 0 (Fail) is returned

TIMER Initiate the TIMER self test. Status of 1 (Pass) or 0 (Fail) is returned

3.3 Capacitance Reading and Status Data Transfer Specification

3.3.1 Capacitance Readings

Capacitance readings are transferred to the external computer as single precision floating point numbers. The number of readings transferred is always the same as the number of channels specified for data acquisition with the STAR and STOP commands.

The readings are sent from start channel to stop channel serially. The RS-232 interface in the external computer and EU will be set for 8 bit data transmission. Thus, 4 "frames" will be needed to send one 32 bit, single precision floating point number. If the MSB of the 32 bit number is 31 and the LSB is 0; the first frame will be bits 7-0, the second frame bits 15-8, the third frame bits 23-16, and the fourth frame bits 31-24. There will be no separator characters between numbers. The PC is inherently organized as low-byte / high byte. The data received in the RS-232 port of the PC will automatically be converted into 32 bit floating point numbers from the transmitted "ASCII frames".

The external controller will know (from a byte count) when the complete set of data has been transfered, but an end of transmit character (carraige return) will be transmitted by the EU at the end of data transfer.

3.3.2 Serial Number Data Transfer

The serial number is to be returned as a 16 bit integer; low byte then high byte.

3.3.3 Test Status Data Transfer

Results of tests requested by the external computer should be returned as a zero for failure and a 1 for pass. The status is to be returned as a 16 bit integer; low byte then high byte.

3.3.4 Data Transfer Performance

A complete scan of 48 channels would result in 48 x 4 = 192 Bytes of data for transfer. Using a "frame" of 10 bits to transfer a byte of data, and 9600 Baud; the data transfer is

Transfer Time = (192 Bytes x 10 bits/frame) / 9600 bits/sec. = 0.2 seconds

4.0 Service Considerations

4.1 Service Data Acquisition Modes

4.1.1 Continuous Acquisition on a Single Channel

4.1.2 Continuous Acquisition on all Channels

4.2 Diagnostice Modes and Troubleshooting Annunciators

ACMS System Operation
External Reference Specification
Revision 1.0, February 16, 1993

Outline

1.0 System Capabilities

2.0 System Components

- 2.1 System Controller
- 2.2 Electronics Unit
- 2.3 Hand Control Unit
- 2.4 System Printer
- 2.5 System Enclosure and Power Supply

3.0 System Software Capabilities

- 3.1 Language and Development Environment
- 3.2 User Access
- 3.3 User Configuration
- 3.4 Calibration
- 3.5 Hole Specifications
- 3.6 Engineering Drawings
- 3.7 Measurement Acquisition
- 3.8 Measurement Database
  - 3.8.1 Indexing of Measurements
  - 3.8.2 Reporting of Measurements
  - 3.8.3 Interface to Other PC Applications

4.0 System Cabling

- 4.1 Physical and Mechanical Requirements
- 4.2 Electrical and Performance Requirements

5.0 Compatability Issues

1.0 System Capabilities

The ACMS system will have the same basic capabilities as, and at least the same basic measurement performance of the current CMS. The major improvement and refinement goals of the new system are: lightweight, battery powered operation; streamlined software operation; system design philosophy to support future developments in small handheld PC's; and measurement data compatability/interface to other PC software applications.

2.0 System Components

2.1 System Controller

The System Controller will be a IBM-AT compatible, laptop computer capable of surviving in the ACMS manufacturing environment.

The touch screen display of the HP 332 computer works well in the current system. It eliminates the need for a keyboard for most operations, thus not requiring the operator to be familiar with typing or computer keyboard operation. We have not had luck finding a touch screen PC-compatible display. There are many touch screen CRT-type displays available but these are unusable due to power requirements. There are a couple of touch screen LCD-type VGA standards displays available but the cost is in excess of $3500. We need to come to grips with a fundamental decision. Can we expect the operator to have some keyboard familiarity and can we make keyboard operation simple enough that "any" operator can learn the system?

We can probably separate the mechanic functions from the engineering functions in terms of operator interface. Engineering functions such as entering drawings, limits, and configurations can use pull down menus, cursor keys, an normal operator interface techniques (try the MS-DOS 5.0 Editor for illustration). The current CMS function is highly driven from the HCU. With a very similar HCU we can expect the same to be true for the measurement function of ACMS. The remaining choices and decisions required by the measurement function can be made to lead the user through operation using the keyboard but may still require the use of pull down menus. It is also possible that we could come to the conclusion that an operator is capable of learning how to use a typical PC application program.

2.1.1 Processing Power

The System Controller must be capable of performing data manipulation at least as quickly as the current HP 332 computer used in the CMS. Data transfer rates between the System Controller and the Instrument must be at least as fast as with the current system. Microprocessor and clock speed will be determined by benchmarking the CMS centering and data reduction algorithm.

From benchmarking on the GEMCOR system, it is anticipated that a 386 based system with coprocessor and 2-4 MBytes of RAM will be found as the acceptable processing configuration. 286 and 8088 compatibles will also be evaluated.

2.1.2 Storage Capabilities

A minimum of 20 MBytes permanent storage will be available in the controller. This storage is needed for calibrations, drawings, specifications, the measurement database and application programs. The controller will also have a 3-1/2" microfloppy drive.

2.1.3 Display Capabilities

It is desired in the first release of the system to have all functionality available in the ACMS controller. A system of operator identification and passwords will be used to qualify entry into various operations of the system (setting specification, modifying drawings, etc.). It is also desirable to have the various graphical displays offered in CMS available in the ACMS controller. These requirements dictate a VGA display.

Operational aspects of each software function will be specified in Section 3.0. At this point it is important to state the requirement that software developed for the CMS and TIPCAL functions in this version of the system is designed to be forward compatible with handheld PC's which may only provide a CGA or more limited display standard. It is unrealistic to require that a handheld PC, with a limited keyboard and display, be used to perform all operations of the system.

2.1.4 Keyboard Capabilities

The controller will have a full QWERTY style keyboard with number pad and function keys

2.1.5 Interaction Between ACMS Controller and Desktop PC's

The non-measurement aspects of ACMS software will be capable of being installed and run on any IBM-AT compatible computer of a specified minimum configuration. This will allow engineers/system managers to enter specifications and drawings at their desk. Results of testing (current PLOT function) can also be obtained in a desktop PC.

The means of exchanging data between the ACMS controller and a desktop PC will be through; 1) the 3-1/2" media or 2) through a simple master/slave communication package running in both computers allowing one computer access to read and write to the disc drives of the other.

The format of the measurement database will be such that the file can be imported directly into popular PC application programs (Lotus, dBASE, SPC packages, etc.)

2.1.5 Networking and Real-Time Communication of Measurement Data

It is intended that, either at release or with a subsequent revision, the ACMS system be capable (optionally) of communicating via an RF link to a central data gathering computer. This functionality is the same basic premise as interfacing to a PC gage port (COM port) as we are now undertaking with Lockheed. Some factory floors will not permit RF communication if flight-line avionics or RF links to heavy machinery (cranes, etc.) are present.

2.2 Electronics Unit

The form and function of the Electronics Unit are specified in a separate document.

2.3 Hand Control Unit

For the first release of ACMS, it is desired to have a Hand Control Unit with similar form and function as the current HCU. The principal improvement will be the selection of indicators that are highly visible in a range of lighting conditions but consume very little power. It is also required to have a 5 digit hole number display. It is highly desirable to have a small text LCD display as well to communicate limited textual instructions and error messages to the operator. There is some study that needs to be undertaken to determine the best method of interfacing the HCU into the system. The ACMS EU has been designed with an HCU interface similar in function to the current CMS.

2.4 System Printer

A lightweight, battery powered printer must be identified for integration in the system. It would be preferable to have the printer integrated into the system enclosure. The printer must support continuous feed paper and be capable of printing at least 50 lines of 80 characters per page.

2.5 System Enclosure and Power Supply

2.4.1 Portable ACMS

The target size for the ACMS system (enclosure, EU, computer, and printer) is X by X by X with a weight not to exceed Y pounds. The system will be battery powered and must be capable of being run continuously for 2 hours on a battery pack. It is desirable to use a battery pack that is commercially available and on Federal stocklists.

2.4.2 ACMS in Automated Environments

3.0 System Software Capabilities

The current CMS uses a touch screen display and a very serial, lead the user by the hand, operator interface. There is a lot of merit in the current operation and organization of the CMS software. We need to start with a clean sheet approach to designing ACMS software but keep in mind what has worked well with CMS. Keyboard and display issues are briefly discussed in Section 2. Determination of the operator interface is first step in the system software development effort. This choice must be made before the development effort can proceed in earnest.

The operator interface falls into two classes; functions that are typically performed off-line by more skilled computer operators (drawings, limits, configurations) and those performed by mechanics (CMS). Calibrating a probe probably falls somewhere in between. We need to develop what a realistic expectation of mechanics' skill levels and prototype a commensurate operator interface approach.

We also need to look at all the choices, functions, and configuration setups in the current system to define what needs to be kept, added, or removed from the system software. Each of the items 3.1 to 3-8 will be defined and developed in detail in separate documents. Basic elements of each function are presented in this summary specification.

3.1 Language and Development Environment

The software for the system could be written in either a BASIC or a C programming language. Consideration for selection of programming environment should include future supportability and support personnel. Consideration should also include attention to the large percentage of actual software code lines that are typically dedicated to operator interface functions.

3.2 User Access

The system will support a means of operator "log-in" and password entry. The file containing the operator and password information will reside on disk in each ACMS. Access to the program to create new operator ID's and passwords will only be accesible to the overall CMS manager

3.3 User Configuration

This is kind of a "messy closet" function in the software right now. However, most application programs have some sort of a Settings... function that serves as a catch-all. A thorough review of all the current user configuration choices will probably pare down the number of choices somewhat.

3.4 Calibration

A guided process for calibrating probe tips similar to the current system will be used. Room for improvement here is in interpreting the results of a calibration. We present microinch spreads for the large and small gage blocks and E and K values. These numbers mean very little except in the rote, trend descriptions we verbally give to customers on how to interpret them. We need to come to understand the calibration results better and the software should be a little smarter in deciding what is a good calibration. It is possible to calibrate the system successfully (no K's < 0), but yield K values that will calculate hole measurements that are not within our "specified" hole tolerances.

It would also be a good idea to adopt the idea of a verification standard. This idea of an independent (different than a calibration standard) artifact is used throughout the electrical and dimensional measurement field. We ought to be able to measure a well characterized hole to its known value within our uncertainty with any calibration accepted by the system.

3.5 Hole Specifications

The current system of assigning "limits and descriptions" to each type of drilled hole works well. A function such as "LIMITS" will obviously exist in ACMS. We will probably find that we can make it much easier to use. One obvious improvement would be to label the specifications instead of numbering 1-99. Selecting spec's to assign to hole numbers in a drawing would be more of a process of choosing '1/4" 1st OS' or 'TL7-2' instead of looking up what is spec 23, etc.

3.6 Engineering Drawings

The current organization of drawings is quite satisfactory. A similar function to generate a drawing file will be included in ACMS. A possible improvement would be to have the option of automatically generating a "mirror" of the drawing starting at 1001 for 1st oversize; and 2001 for 2nd oversize. This would be particularly handy for rework applications where the size of holes found doesn't always match the original hole size.

3.7 Measurement Acquisition

ACMS will have drawing based, and non-drawing ("Tool Crib") based modes of operation. It will be possible in the CMS function to configure choices for printout, storage, and gage output of data. A concurrent hardcopy printout of CMS activity will be maintained. The last hole measured will be able to be plotted. The ability to generate a plot of any previous reading or summary printout will be available will be available in the equivalent of the current PLOT function. Once the CMS function is in the "READY FOR TEST" mode, operation from the HCU will be very similar to the current system. It would be desirable to be able to specify a probe change from the HCU in the non-drawing mode of operation.

3.8 Measurement Database

3.8.1 Indexing of Measurements

Measurements will be stored and indexed by operator, date/time, drawing, assembly #, probe serial #, hole#, and hole disposition. These indexes along with the high/low specification, min/max/avg reading, and 48 segment values will take about 264 bytes/ measurement. Allowing a maximum total of 32,676 readings (ability to index the database record with an integer value pointer) would consume less than 10 MBytes maximum disc space.

3.8.2 Reporting of Measurements

Summary reports can be generated sorted by any combination of database indexes. For example; all BAD readings taken on assembly #10 with probe 179A045 could be reported.

3.8.3 Interface to Other PC Applications

The measurement database will be format compatible with Lotus 1-2-3, Microsoft Excel, DBASE, and selected SPC packages. "Gage Output" can be turned on and off in the CMS function. Gage output can be directed to a file or a serial port. The serial port will at some point have the capability to communicate over an RF link to a central computer.

4.0 System Cabling

4.1 Physical and Mechanical Requirements

4.2 Electrical and Performance Requirements

5.0 Compatability Issues

The ACMS electronics unit will be compatible with older red cart systems. Changes will be made in the HP software to recognize which EU is present and autoconfigure accordingly. Ed Pratt has specified his desire that data from an ACMS could be analyzed on a red cart HP computer. The current CMS database is somewhat fractured by the ancient past. Much of the entries in the database are integer values that represent different concantonations/combinations of measurements and setups. This was very necessary in the days of cassette tapes and floppies with 360K storage. There would be no rational to organize the ACMS database along these lines. This would create some (2-3 weeks) work in HP BASIC to allow the HP to read, sort, and report ACMS database format.

ATTACHMENT B

May 17, 1994

MEETING SUMMARY

Notes on meeting with Ed Pratt for 1/12

References to
Specification: 91-LJLE-013, Rev. 1, 6/28/93
Statement of Work: , Rev 2, 6/28/93
Prototype Test and Evaluation Plan 11/30/93

1. Prototype Test and Evaluation Plans

Ed's Prototype Test and Evaluation Plan states the following general requirements:

a. Ease of use: Includes handling of unit, ease of screen viewing, etc.

b. Reliability and Maintainability: Total operating time, number of failures, and type of failures will be recorded during the evaluation perioe

c. Software: The software will be evaluated for glitches and user friendliness. The software will also be evaluated to insure all aspects are available which are required by the contract.

d. The evaluation period will be for three working weeks.

It seems to me that this is an appropriate plan. The problem for us is that we would like to go ahead and nail down any hardware changes we are going to make right now. Software "to insure all aspects are available which are required by the contract" will not be ready for 8 weeks. I'm sure that Ed is already happy with what he has seen in the packaging and that we can get him to render his blessing for us to proceed with the enclosure.

The only change we are making to the enclosure is a slight stretch to the width of the enclosure for accomodating the off-the-shelf handle component and for a slight improvement in assembly of the computer/display component. This width change will still allow the unit to pass through the "magic porthole". We will also be tweaking a few hole locations and fastener selections. We will also produce the front cover. The front cover has not been prototype thusfar because of the enclosure width change. It was not practical to tool up to make a cover for the first three enclosures and throw away the tooling.

2. Assuring that Ed's software expectations match our own

Ed's software requirements are spelled out in Section 3.x.x of the Specification. They are very general representations and state the basic features of CMS. The only additional work spelled out in Ed's spec that we might not otherwise undertake is described in 3.10 to 3.10.2 regarding the transfer of hole data from ACMS to the CMS computers and drawing transfer from the CMS computers to the ACMS. These are not huge tasks and we can at least provide them to other existing customers (especially drawing and limit conversion) as a service when they upgrade to ACMS.

The area we must be careful not to avoid duplication of effort is in the way we implement the specified feature set on ACMS. If we keep Ed in the loop during the design of the different screens and processes, we should not have any trouble at the end. This will take a little time along the way but will avoid rework at the end of the project. I doubt that there is very much that Ed will disagree with Tim and Chris about if included in the development.

To this end we will go ahead and develop a paper model of what each screen, menu, and measurement process will be. This should also help us internally to make sure that development time is spent as efficiently as possible.

Impressions of ACMS Status Meeting with Ed Pratt 1/14/94

1. Selection of unit for evaluation test plan and purchase option

We showed Ed working prototypes of both the battery powered, LCD display ACMS and the AC powered, EL display ACMS. The EL display is much brighter and can be viewed from a wide range of angles, however the EL display consumes too much power for a battery powered configuration. The LCD display is consumes little enough power for a battery configuration, but is not as viewable.

Ed decided to proceed with the AC/EL combination. Some specification changes obviously must be made to the contract. Ed indicated that it would be just as easy for him to wait until he felt like he knew all of the changes he would be submitting and would effect the no battery mode needed change at that point in time.

2. System software discussions

We discussed the "look and feel" goals for both mechanic (CMS) functions and engineer (CDRAW, LIMITS, etc.) functions. For the mechanic, it was generally determined that the touch box, "software guiding the operator" approach of the current system and ACMS prototype was appropriate. Ed also liked the combination keyboard entry / touch box approach of the "engineer" functions in the current system. We will proceed along those lines with software operator interface.

There are quite a few options and user configuration choices in the current system. We went over them individually to rate the merits of each. Ed was generally in agreement with the choices Chris and I had made earlier. We did not present our previous choices to Ed to avoid biasing his inputs. This resulted in closure on user configurations in the software. Ed's RAFB inputs matched our own product plans for general use.

There was one section in Ed's spec. that required the ability of an HP R3x2 CMS controller to be able to read and display RESULTS files from an ACMS. When asked the reasoning behind the request, Ed indicated that he wanted to be able to generate summary printouts/plots without having to tie up a measurement system. We offered the capability to be able to perform these functions, by moving floppy discs around, on any properly configured PC instead. Ed like that even better. This also fits better with our own vision of data portability for the product. We already plan to offer this capability anyway. This change will also need to be made to the contract specification.

ATTACHMENT C

May 17, 1994

DEFICIENCY REPORT FORMS

Advanced Capacitance Measurement System (ACMS, CMS II)
Deficiency Report Form

Name Ed Pratt - WR-ALC

Date March 17, 1994

Problem Description (if software include any steps necessary to recreate the problem):

Limits

In [Delete ALL] we should have "Are you sure" [YES] [NO] boxes.
If [YES] enter Password.

Suggested Changes:

Change/Fix incorporated into deliverable software.

Advanced Capacitance Measurement System (ACMS, CMS II)
Deficiency Report Form

Name Ed Pratt - WR-ALC

Date March 17, 1994

Problem Description (if software include any steps necessary to recreate the problem):

Unknown Hole

The display should be as follows [Spec 2 -179A - 1/4 B Fit] instead of the way it is now.

Suggested Changes:

Change/Fix incorporated into deliverable software as well as the Tool Crib Software.

Advanced Capacitance Measurement System (ACMS, CMS II)
Deficiency Report Form

Name Tim Semones - MSI

Date March 30, 1994

Problem Description (if software include any steps necessary to recreate the problem):

Limits

The [Cancel] box in all limits is incorrect

Suggested Changes:

Change/Fix incorporated into deliverable software.

Advanced Capacitance Measurement System (ACMS, CMS II)
Deficiency Report Form

Name Tim Semones - MSI

Date March 30, 1994

Problem Description (if software include any steps necessary to recreate the problem):

At the end of "un-numbered hole" keep enteries

Suggested Changes:

Change/Fix incorporated into deliverable software.

Advanced Capacitance Measurement System (ACMS, CMS II)
Deficiency Report Form

Name Ed Pratt - WR-ALC

Date March 17, 1994

Problem Description (if software include any steps necessary to recreate the problem):

Drwaings

1. When entering holes automatically prompt for next hole
2. Headings wrong for [Grip], [CS/NCS] and [Spec #]

Suggested Changes:

Change/Fix incorporated into deliverable software.

Advanced Capacitance Measurement System (ACMS, CMS II)
Deficiency Report Form

Name Ed Pratt - WR-ALC

Date March 30, 1994

Problem Description (if software include any steps necessary to recreate the problem):

More than one screen worth of drawings will not lead the operator to the next screen.

Suggested Changes:

Change/Fix incorporated into deliverable software.

Advanced Capacitance Measurement System (ACMS, CMS II)
Deficiency Report Form

Name Tim Semones - MSI

Date March 31, 1994

Problem Description (if software include any steps necessary to recreate the problem):

Choose [Print Drawing] with no printer causes a Protect Fault by the computer.

Suggested Changes:

Change/Fix incorporated into deliverable software.

Advanced Capacitance Measurement System (ACMS, CMS II)
Deficiency Report Form

Name Tim Semones - MSI

Date April 25, 1994

Problem Description (if software include any steps necessary to recreate the problem):

1. Measurement Averages - Five (5) times

2. Default Plot Format will follow any changes made.

3. Clear Screen after [Changes/Option] and [Pass Bad]

Suggested Changes:

4. Send [Pass Bad] information to printer as done. For example, "Good Now [Operator Name]".

5. Cancel Check-Off - Clean up.
automatically go into unknown hole routine.

Advanced Capacitance Measurement System (ACMS, CMS II)
Deficiency Report Form

Name Chris Ratcliffe - MSI

Date March 31, 1994

Problem Description (if software include any steps necessary to recreate the problem):

1. [Check Off] to [Screen] to [Session] it looks for a printer.
2. [Check Off] to [Cancel] leaves "check off to screen" prompt on screen
3. If the printer is not on-line in [Data Analysis] [Print Now] allow for a [Try Again] box.

Suggested Changes:

Changes/Fix incorporated into deliverable software.
automatically go into unknown hole routine.

Advanced Capacitance Measurement System (ACMS, CMS II)
Deficiency Report Form

Name Ed Pratt - WR-ALC

Date March 31, 1994

Problem Description (if software include any steps necessary to recreate the problem):

Cant access unknown hole routine (9#) until after your in the system under a known hole number.

Suggested Changes:

During initial setup if 9XXX is selected as hole number, automatically go into unknown hole routine.

Advanced Capacitance Measurement System (ACMS, CMS II)
Deficiency Report Form

Name Ed Pratt - WR-ALC

Date March 21, 1994

Problem Description (if software include any steps necessary to recreate the problem):

When inputting drawings, their location cant be moved on the screen. The left drawing is not always beside the right.

Suggested Changes:

Sort by drawing name before displaying drawing list.

Advanced Capacitance Measurement System (ACMS, CMS II)
Deficiency Report Form

Name Jeff Arnold - WR-ALC

Date April 12, 1994

Problem Description (if software include any steps necessary to recreate the problem):

Display screen is too dim for outside conditions.

Suggested Changes:

Brighten screen or change screen color.

This requested change is not possible.

Advanced Capacitance Measurement System (ACMS, CMS II)
Deficiency Report Form

Name Ed Pratt - WR-ALC

Date May 2, 1994

Problem Description (if software include any steps necessary to recreate the problem):

Check-Off Program

If there are a large number of holes in check-off, the holes numbers write across the [Return] box in the left corner of the screen.

Suggested Changes:

Change/Fix incorporated into deliverable software.

Advanced Capacitance Measurement System (ACMS, CMS II)
Deficiency Report Form

Name Ed Pratt - WR-ALC

Date May 2, 1994

Problem Description (if software include any steps necessary to recreate the problem):

User Program

After each entry such as [Decimal], [Autoplot], [Auto Grip], [Level Avg], [MM, Inches] the screen does not clear.

Suggested Changes:

Change/Fix incorporated into deliverable software.

Advanced Capacitance Measurement System (ACMS, CMS II)
Deficiency Report Form

Name Ed Pratt - WR-ALC

Date May 2, 1994

Problem Description (if software include any steps necessary to recreate the problem):

Suggested Changes:

Drawing Program

Request to have drawing XXXX100L (Left) and XXXX100R (Right) beside each other in the drawing screen. It would be difficult and time consuming. Not on the original request/SOW. Possibly could be done at a later time.

Advanced Capacitance Measurement System (ACMS, CMS II)
Deficiency Report Form

Name Ed Pratt - WR-ALC

Date April, 1994

Problem Description (if software include any steps necessary to recreate the problem):

The power plug in receptable on the prototype system is loose. Gene Price of Measurement Systems informed of this potential problem.

Suggested Changes:

Change/Fix above incorporated into deliverable software.

Advanced Capacitance Measurement System (ACMS, CMS II)
Deficiency Report Form

Name Ed Pratt - WR-ALC

Date April 21, 1994

Problem Description (if software include any steps necessary to recreate the problem):

The number '9' does not work under [NEW HOLE #]. It will work under "UN-NUM HOLE".

Suggested Changes:

Automaticlly switch to UN-NUM HOLE if the number '9' is selected in [NEW HOLE #].

Changes above incorporated into deliverable software.

Advanced Capacitance Measurement System (ACMS, CMS II)
Deficiency Report Form

Name Ed Pratt - WR-ALC

Date April 21, 1994

Problem Description (if software include any steps necessary to recreate the problem):

Unnumbered Holes have to go thru the entire setup to change hole numbers. The increase and decrease buttons on the Hand Control Unit (HCU) will not function.

When turning system on for the first time, you cannot run unnumbered holes until you go thru procedure for numbered holes first.

Suggested Changes:

Changes above incorporated into deliverable software.

Advanced Capacitance Measurement System (ACMS, CMS II)
Deficiency Report Form

Name Kay Cole - WR-ALC

Date March 17, 1994

Problem Description (if software include any steps necessary to recreate the problem):

Limits Program

The ability to enter a large number of limits - over 100.
Bottom right box must be a [NEXT SCREEN] or [CANCEL].
Next screen to go further into Limits or cancel to return to Main Menu.

Suggested Changes:

Changes above incorporated into deliverable software.

ATTACHMENT D

May 17, 1994

ACMS GENERAL INFORMATION

Capacitance Measurement System II

Modern aircraft can have as many as a quarter of a million structural fasteners. The integrity of each structural fastened joint is paramount to the overall reliability and safety of the operational aircraft. Consequently, the precise size and tolerance of both the fasteners and mating fastener holes are of critical importance. The resulting inspection and quality assurance requirements can be both expensive and time consuming especially where 100% inspection is required. The Capacitance Measurement System II takes 48 dimensional measurements of either a fastener or a fastener hole, compares these measurements with preset specifications, and signals the operator with a red or green light on the measurement's acceptability. All the quality parameters of each measured part can be graphically displayed to assist in corrective action. All measurements are permanently recorded for further reference and process control (SPC) purposes.

ALL IN JUST TWO SECONDS

SPECIFICATIONS

Standard Equipment List

- IBM-AT Compatible Touch Screen Controller with:

386 SX Processor
Math Co-Processor
80 MB Hard Disk Drive
78 MB for Data Storage

VGA Display
2MB Random Access Memory (RAM)
Keyboard/Mouse Compatible
Serial/Parallel Ports for Printer Interface

- Connecting Cables
- Operator Manuals
- Hand Control Unit
- Set-Up & On-Site Training

PROBES AVAILABLE FOR THE FOLLOWING DIAMETER SIZES:

0.1645" - 1.500" (4,17 - 38,1 mm)
Straight Holes and Fasteners
Tapered Holes and Fasteners

TYPICAL ACCURACY

+/- .0002"
+/- .005mm

PHYSICAL DIMENSIONS AND WEIGHT

13" X 12" X 10" 25 Pounds
33cm X 31cm X 25cm 11 kilos

POWER REQUIREMENTS

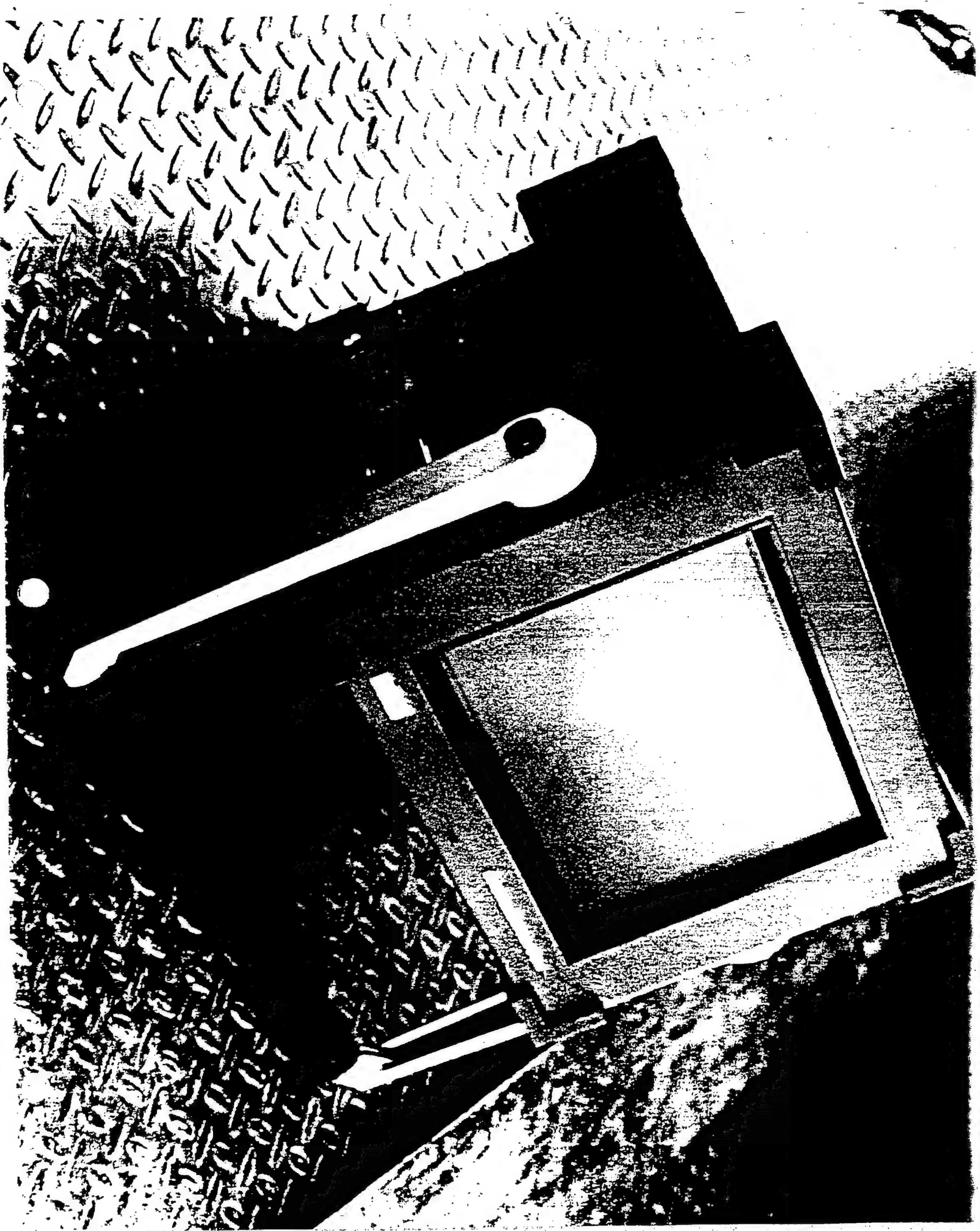
AC Power Only Option	Part Number ACM0001-101A
Battery Power / AC Power Option	Part Number ACM0001-102A
European Power Option	Part Number ACM0001-103A
European Battery Option	Part Number ACM0001-104A

OPTIONAL FEATURES

Customized Software
SPC Compatible Software
Travel/Transport Case
Additional Hard Disk Storage

Contact an MSI representative to discuss specific details of your measurement application.

CORPORATE OFFICE: 2262 Northwest Parkway, Suite B, Marietta, GA 30067 USA Phone (404)951-0878 Fax (404)951-8920
EUROPEAN OFFICE: Violetstraat 13, B 3580 Beringen, Belgium Phone Int+32-11-434868 Fax Int+32-11-434866



ATTACHMENT B

August 1, 1994

PHOTOGRAPH OF FINAL DESIGN ASSEMBLY

ATTACHMENT C

August 1, 1994

SOFTWARE REVISION ACTIVITY REPORT

Revision Activity Report

ACMS Revision 1.00

Item #	Bug/Enh	Item Description	Proposed Revision	Status A-Active I-Inactive C-Complete	Comments	Time Estimate (hrs)
1	E	Can drawing filenames be > 8 characters	N/A	I	Limitation of DOS filenames to 8 characters	N/A
2	E	Ability to change description in Modify Drawing	1.1	A	Easily changed	1 to 2
3	E/B	Display drawings in alphabetical order	1.1	A	There are several of this type. No 'C' sorting routine causes us to write own	8 to 12
4	B	"Ghost" boxes in Display Limits	1.1	A	Easily fixed	0.5
5	B	Calibrate resets default plot mode	1.1	A		4
6	E	Stop Printing choice where appropriate	1.1	A	Should be relatively straightforward, may take a little while	4 to 6
7	E	Include level averages in Data and DOS files		I	Will require a modification in Ashley's database code for DOS files	8
8	B	Ed's password bug	1.1	A	Strange behavior, will find and fix	2 to 4
9	E	Screen plots of selected range of readings		I	Will investigate	
10	E	Page Down and Up in Data Analysis		I	Page Down is a key re-label, Page Up will require a database change to find prev. record	
11	B	DOS files in mm mode	1.1	A	File output is now always in inches, simple change in database	2
12	B	Plot Now in Data Analysis other than Circle Plot	1.1	A	STC (Slipped through cracks)	2
13	B	Data Ana/Display Now not lined up sometimes	1.1	A	Problem occurs if last digits are "0"	2
14	B	Limits are shown to 5 places always	N/A	I	Some tapered stds. require this, # of digits refers to CMS display and PASS/FAIL compare	N/A
15	B	Software get confused from mm to In. and back	1.1	A	Will investigate	2 to 4
16	B	Random Hole# and spec causes Run-time error	1.1	A	Should be an easy fix	1
17	B	Hole # not on drawing causes blank CMS Test Scr	1.1	A	Should be an easy fix	1
18	B	CMS/Plot Prev put previous reading in Test Scr	1.1	A	Should be an easy fix	1
19	E	Screen Saver reacts to HCU		I	Would require substantial rework in Ashley's SS and Ernies' code, feature not worth it?	
20	E	Use Calibration Standard not calibration standard	1.1	A	Trivial	0.25
21	E	Change INC and DEC to INCR and DECR	1.1	A	Trivial	0.25
22	E	Use Calibration Std not Gage nomenclature	1.1	A	Trivial	0.5
23	E	Limits and Drawings use different verbage for Spec	1.1	A	Trivial	0.25
24	B	Data Analysis / Operator Recall cap letters	1.1	A	Should be easy, will require re-entry of ID file by current users is small letters used	1
25	B	Tip File Generator	1.1	A	Not finished for 1.0	8
26	E	Ignore Level Capability	1.1	A	This change would have a pretty significant ripple effect	16
27	E	New HCU Support	1.2	I	Time with New HCU Intro	
28	E	Finish Drift Test and Shop Test Routines for Gene	1.1	A	Drift test for ACMS - 1 day; General Shop and train Gene for stand-alone-3 days	24 to 32
29	E	Expanded Printer Support	1.1	A	Now only HP Quiet/Desk/Lasers; currently screen dumps, need to change to mem buffers	32 to 40
30	E	Autogrip Mode	1.1	A	Post-processing process, develop empirically and experiment with	12 to 16

ACMS QA
Change Operator and Operator ID's

Test Suggestions:

1. Create a set of users of varying access level and verify access operation.

2. Copy the operator ID files to floppy disk, etc.

3. Print and display the operator ID's

Additional Information:

1. There are 4 access levels in the system. Level 1 is for MSI factory personnel and the customer system administrator. Level 2 is for QA personnel. Level 3 is for Metrology personnel. Level 4 is for mechanics. These are a combination of RAFB and DA requests.

2. The software does not ask for the operator name and password, just the password. The operator name (corresponding to the password) entered in the Operator ID's choice in the Utility Menu is placed in the RESULTS file and on printout.

3. The operator ID file in an ACMS unit is a "hidden" file. It is not accessible from the DOS prompt or in a word processor. This yields some security to the system. It is not however fool-proof. The access to "unhide" a hidden file is available in utilities such as XTree but it would take a very PC-savvy mechanic to work through this.

   When the operator file is copied from hard disk to floppy disk, the file is unhidden on the floppy so that the system administrator can see what he has if desired. When an operator ID file is copied from the floppy to the hard disk, the file is "re-hidden" on the hard disk.

ACMS QA
CMS Module

Test Suggestions:

1. Wring the sucker out good!

Additional Information:

1.

To Come or Be Fixed:

1. Pass bad hole has a bug in it right now. It will be fixed this week before shipment.

2. Graphics dump is only supported at introduction for a QuietJet, LaserJet, or DeskJet printer. Basically any parallel printer will work for text printing. This is going to be a nice little project for the next revision. Basically, we do not have enough control over the image the way that I am currently dumping the display directly to the

3. Will try to make the quick changes to our hole graphics to display Levels 1-6 instead of Levels 0-5. Also show arrows on X-Sect and Linear for maxspec-minspec.

ACMS QA
Limits

Test Suggestions:

1. Create a set of appropriate limits. Use a variety of limit numbers (i.e. 1, 23, 365, 1000)

2. Try to erroneously enter a limit definition

3. Try to delete and modify existing limit specs.

Additional Information:

1. Copying a LIMITS file from floppy disk to hard disk will replace any existing limits definitions in the system.

2. The LIMITS file in an ACMS unit is a "hidden" file. It is not accessible from the DOS prompt or in a word processor. This yields some security to the system. It is not however fool-proof. The access to "unhide" a hidden file is available in utilities such as XTree but it would take a very PC-savvy mechanic to work through this.

   When the LIMITS file is copied from hard disk to floppy disk, the file is unhidden on the floppy so that the system administrator can see what he has if desired. When a LIMITS file is copied from the floppy to the hard disk, the file is "re-hidden" on the hard disk.

ACMS QA
Drawings

Test Suggestions:

1. Create a set of drawings. Attempt to display, print, modify, delete, and rename drawings.

2. Try to erroneously enter a drawing definition

3. Try to copy drawing files back and forth from floppy to hard disk.

Additional Information:

1. Ignore Levels didn't make the feature cut and will be included in the first revision.

ACMS QA
Calibration Module

Test Suggestions:

1. Perform careful calibrations with straight and tapered probes, 3/16" and larger. Print a calibration to the printer.

2. Plot gage readings and use the Verify Cal feature to measure a verification device with the calibration just performed. Dump a plot from either a gage reading or a verification standard to the printer.

3. Try to perform a bad calibration to force math errors or strange behavior

4. Display and print the list of calibrated probes on the system .

5. Copy cal files to floppy disk, try also with no disk in drive.

Additional Information:

1. There are 4 access levels in the system. Level 1 is for MSI factory personnel and the customer system administrator. Level 1 can pass a bad cal if desired. Level 2 is for QA personnel who can not pass a bad cal. Level 3 is for Metrology personnel who can not pass a bad cal. Level 4 is mechanics, who do not have access to calibration.

2. The acceptance criteriion for a calibration is:
   no negative K's
   all K's in a level must be within +/- 30% of the mean K for that level
   ESUM's must be less than .001

3. The software will present an numerical ascending list of probes calibrated in the system. Right now there is a 100 calibration maximum. If more than 100 calibration files exist, the software will inform the user that too many calibrations exist to display.

To Come or Be Fixed:

1. The ability from the Calibrate Menu to recall a previous calibration for printout, gage reading, verify, etc. (next revision)

ACMS QA
Data Analysis Module

Test Suggestions:

1. Perform careful calibrations with straight and tapered probes, 3/16" and larger. Print a calibration to the printer.

2. Plot gage readings and use the Verify Cal feature to measure a verification device with the calibration just performed. Dump a plot from either a gage reading or a verification standard to the printer.

3. Try to perform a bad calibration to force math errors or strange behavior

4. Display and print the list of calibrated probes on the system .

5. Copy cal files to floppy disk, try also with no disk in drive.

Additional Information:

1. This module works by defining a database "query" and outputing the results of the query. There are 4 choices for "output". Plot Previous will display a hole graphic for one hole recalled by reading number. Display Now will page through the selected database query on the screen. Print Now will output the selected query to the printer. Plot Now will output a hole graphic for each element of the selected query to the printer.

2. Save DOS File will output the results of the RESULTS file query to a DOS application compatible ASCII file.

3. File Manager choice allows the RESULTS file to be copied to a floppy disk or a new results file created.

To Come or Be Fixed:

1. Save DOS file outputs measurements in English units currently. I may be able to change this before BA shipment.

2. Save DOS file currently is fixed in the number and types of columns output. A future revision would allow a user to define which columns he would like output to the file.

3. Operator name sorts can be wrong if the operator was entered with upper and lower case letters in Operator ID's. Operator Name entry in Data Analysis is all capitals. This will be fixed prior to shipment.

ACMS QA
Utilities Module

Test Suggestions:

1. Try all features in the User Config Menu

Additional Information:

1. Funct. Test is not quite done yet but will be before shipment. Continuous raw count is the only test routine currently accessible.

2. Return to DOS is only accessible to access level 1 users.

To Come or Be Fixed:

1. Probe Tips may not be ready for first shipment but is really not an issue for this week. We have a way of creating an ACMS tip file from a CMS tip file and this is not a customer documented feature anyway.